MARINE COATING PERFORMANCE
TEN YEAR REPORT

Prepared by
Associated Coating Consultants
Galveston, Texas
in cooperation with
National Steel and Shipbuilding Company
San Diego, California

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FOREWORD

This project was performed under the auspices of the National Shipbuilding Research Program. The project, as a part of this program, is a cooperative cost shared effort between the Maritime Administration and National Steel and Shipbuilding Company. The applied research and development was accomplished by Associated Coatings Consultants under subcontract to National Steel and Shipbuilding Company. The overall objective of the program is improved productivity, and therefore, reduced shipbuilding costs.

This study has been undertaken with this goal in mind, and has followed closely the project outline approved by the Society of Naval Architects and Marine Engineers (SNAME) Ship Production Committee.

Mr. James Ruecker of National Steel and Shipbuilding Company is the R&D Program Manager responsible for technical direction and publication of the final report. Program definition and guidance was provided by the members of the SP-3 Surface Preparation and Coatings Committee of SNAME.

Special thanks are given to Mr John Peart for providing technical direction and the following suppliers for supplying materials which made this project possible:

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Farboil, Baltimore, Maryland
Hempel Marine Paints, Houston, Texas
Imperial, New Orleans, Louisiana
International Paint Company, New York, New York
Mobil, Edison, New Jersey
Mobile Paint Manufacturing Company, Mobile, Alabama
Napko, Houston, Texas
Pfizer Inc., Groton, Connecticut
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Sigma, New Orleans, Louisiana

Executive Summary

The objective of this project was to continue a series of exterior test performance studies which began in 1978 and 1980 as portions of other projects. For a nominal investment, the program has continued for over ten years and is now beginning to provide meaningful test results. For the first time, shipyards have access to field test data systematically developed from exposure specimen where the application was controlled and the characteristics of the applied film was carefully defined and documented. Failure assessments were made at planned intervals utilizing standard evaluation techniques. The marine exposure selected, while not as harsh as experienced by ships at sea, posses sufficiently similar exposure elements to provide significant data to evaluate and compare various generic coating systems utilized for these applications. Even though the state-of-the-art has progressed since the program was initiated, many of the products tested are still available as originally formulated or have been reformulated to improve service life. Stated another way, shipyards now have data which can be used to predict the performance of marine coatings in service.

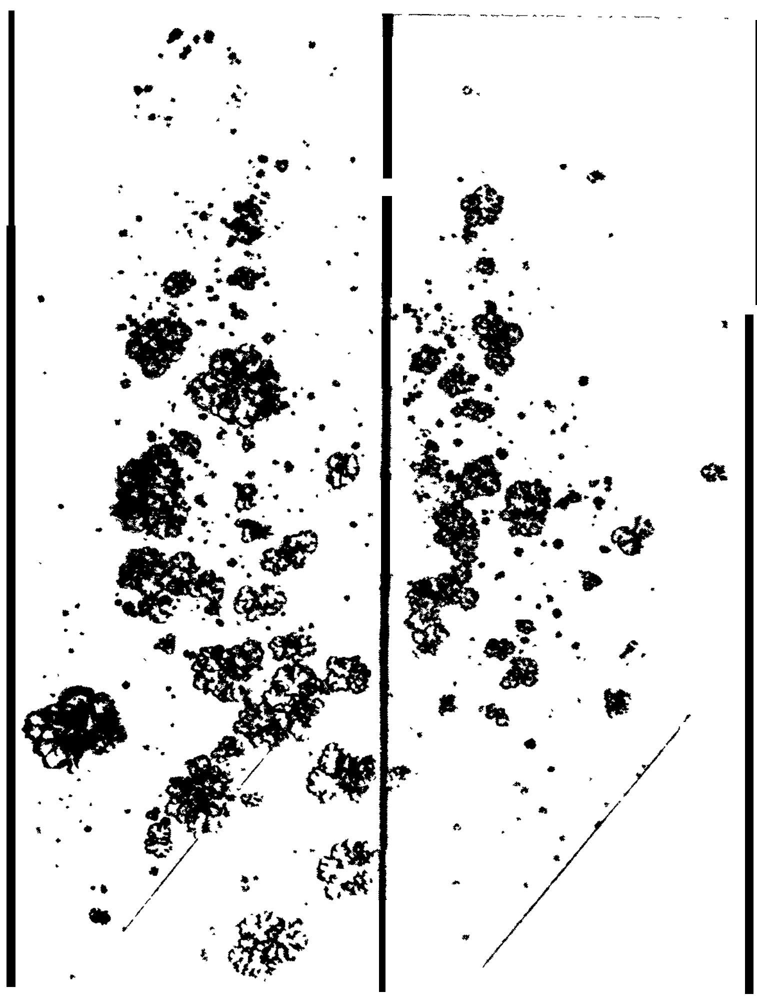

FIGURE 2.1: INORGANIC ZINC\EPOXY SYSTEM WITH MOSS

Project Results

1.1 Project Overview

This project is a continuation of two performance test programs which began in 1978 and 1980. The first program was entitled "Marine Coatings Performance for Different Ship Areas" and the second was "Cleaning of Steel Assemblies and Shipboard Touch-Up Using Citric Acid". Both programs included accelerated laboratory testing techniques such as Salt Fog Cabinets and Light-and-Water-Exposure Apparatus and exterior Test Fence Exposure (45 Degrees South). This report contains the results of the exterior test fence performance after ten years of exposure. In addition, various abrasives were used to prepare the substrate of some panels prior to coatings application. Four different types of abrasives were used to prepare panels to which various inorganic zinc primers were applied, and two types were used to prepare the panels to which the generic coating systems were applied. The four abrasives were silica sand, mineral sand, coal slag, and GL-40 steel grit. The two types were mineral sand and GL-40 steel grit.

This report should not be used to qualify, disqualify, compare or select a given supplier or system. The materials used were standard, off-the-shelf materials with no controls exercised to insure that the materials were acceptable prior to use. In addition, no attempt was made to carefully control film thickness; therefore, the test thicknesses of similar generic products may vary significantly. In some cases, the products tested have been reformulated and\or product designation changed. Some are no longer manufactured or recommended for use as tested. The purpose for presenting the data is to compare the general performance of various generic materials and to better understand degradation processes and failure mechanisms. It should be noted that the mechanisms experienced were due to inherent weaknesses of the generic resins to the weathering environment free of the influences due to shipyard application and production methods.

The results and conclusions of this project are as follows:

1. Most generic exterior coating systems continue to provide some degree of protection to the steel substrate after ten years exposure even though some topcoats have failed.

2. Of the systems tested, the inorganic zinc\epoxy/aliphatic polyurethane demonstrated the best overall performance.

3. The degree of undercutting protection provided by inorganic zinc primer does not appear to be film thickness dependent. Of the 56 systems tested, 31 had some degree of undercut.

4. More chlorinated rubber systems totally failed (3 of 8 tested) than any other generic type tested. This supports the actual case history analysis of "Marine coatings per-

formance for Different Ship Areas" study which found that inorganic zinc with epoxy topcoats outperformed inorganic zinc with chlorinated rubber topcoats.

5. The type of abrasive had no measurable impact on overall coating performance.

6. Primers applied over citric acid cleaned steel performed as well as, or superior to, the same primer applied over abrasive blast cleaned steel.

7. Of the primers tested, the post cured, two component inorganic zinc provides the best corrosion protection. No visible rust present after 8 years of testing.

8. Two component, alkyl inorganic zinc performed better than both the one and two component zinc rich epoxy primers.

1.2 Continued Research

The test fence program should be continued to determine at what point the balance of the systems under test fail. This data can then be used to predict service life of the various generic coatings and coating systems.

2.0 Details of the Program

2.1 Marine Coating System Performance Study

This portion of the test program was initially formulated to verify or support actual case histories collected as a part of the original "Marine Coating Performance Study". The exterior freeboard was selected as a representative area. This area was chosen because of the availability of the test environment and the possible potential of collecting adequate numbers of historical data.

2.1.1 Systems Tested

Table I includes the Paint Systems tested. In general, ten suppliers submitted wet samples of paint which were product matches for the generic description of the requested systems. Five primary systems were compared with some alternates being tested. The primer in all cases was a solvent based, (alkyl) inorganic zinc. The topcoats were polyamide epoxy intermediate with and without topcoats of either aliphatic polyurethane, silicone alkyd, or alkyd. The other systems had intermediate and topcoats of either chlorinated rubber or vinyl. The film thicknesses listed are actual film thickness measurements.

2.1.2 Test Panel Preparation

The steel panels used for testing were ASTM A-36, 6" X 18" x 1/4" hot rolled plate. All panels were abrasive blasted to Steel Structures Painting Council Surface Preparation Standard, ssPc-

SP10, "Near White". Two types of abrasives were used to prepare the panels-mineral sand and steel grit. Some systems were applied over both mineral sand and steel grit prepared substrates and 'some were only applied over steel grit blasted surfaces. A senior laboratory technician skilled in paint application applied each coating. Material application data sheets supplied by each manufacturer were used to determine thinning, application and overcoat time requirements. No special procedures nor special considerations were granted, and no controls were exercised to precisely control film thickness.

2.1.3 Test Environment

The prepared and painted test panels were exposed on an exterior test rack at 45 degrees South in Jacksonville, Florida less than 100 yards from the St. John's River. The St. John's River at this location has a salt content very similar to the Atlantic Ocean which is less than 2 miles away.

2.1.4 Evaluation Techniques

Panels were evaluated for rust, chalk, gloss, cracking, blistering and checking using the following ASTM Standards:

Evaluating the Degree of Rust	ASTM D610
Evaluating the Degree of Chalk	ASTM D659
Evaluating the Degree of Gloss	ASTM D523
Evaluating the Degree of Checking	ASTM D660
Evaluating the Degree of Cracking	ASTM D661
Evaluating the Degree of Blistering	ASTM D714

Complete failure for the generic coating systems (see TABLE I) was judged to occur at such time as one or more topcoats delaminated/detached from the test panel. In some cases, the inorganic primer continued to provide corrosion protection to the steel substrate after topcoat failure. Blistering without delamination or peeling, i.e. the film still intact, was noted but not reported as a failure. For primer only test panels (TABLES V, VI and VII) total failure was judged to occur at ASTM Rust Grade 1 (50% failure).

Table I: Various Generic Coating Systems Exposed On Exterior Test Rack (45 South)

Generic Type	Supplier	Abrasive Type	Product No.	Film Thickness	Rating (10 Yrs.)
Inorganic Zinc	Ameron	GL-40 Steel Grit	D-6	5.0	10-Rust Gloss Not Evaluated
Synthetic TieCoat			54TC	1.5	Flat Finish
Vinyl copolyner		Mineral Sand	99	1.1	10-Rust Gloss Not Evaluated
Vinyl copolymer			99	3.6	Flat Finish
Inorganic Zinc	Ameron	GL-40 Steel Grit	D-6	5.0	10-Rust 8-Erosion @ 6 Years
Polyamide Epoxy			66	3.0	
Polyamide Epoxy		Mineral Sand	66	4.0	10-Rust 8–Erosion @ 6 Years
Inorganic Zinc	Ameron	GL-40 Steel Grit	D-6	4.0	l0-Rust 6-Chalk @ 1 Year
Polyamide Epoxy			383	2.5	87% Loss of Gloss @ 3 Months.
Polyamide Epoxy		Mineral Sand	383	5.5	Moss @ 8 Years. 10-Rust 6-Chalk @ 1 Year. 87% **LOSS** of **G1oss** @ 5 Months. Moss @ 8 Years.
Inorganic Zinc	Ameron	GL-40 Steel Grit	D-6	4.3	10–Rust 9.5-Chalk @ 1 Year.
polyamide Epoxy			71	1.5	50% Loss of Gloss @ 1 Year.
Silicone Alkyd			5403	2.6	Checking @ 8 Years.
Silicone Alkyd		Mineral Sand	5403	1.0	10-Rust 9-Chalk @ 1 Year. 50% Loss of Gloss @ 1 Year. Checking @ 8 Years.
Inorganic zinc	Ameron	GL-40 Steel Grit	D-6	4.6	10-Rust 1/32″ Undercut @ Scribe.
Polyamide Epoxy			71	1.9	9-Chalk @ 1 Year. 46% **LOSS** of **G1oss** @ 1 Year.
Aliphatic Polyurethane		Mineral Sand	2119	1.7	lo-Rust
Aliphatic Polyurethane			2119	3.7	1/16″ Undercut @ Scribe 9-Chalk @ 1 Year 41% Loss of Gloss @ 1 Year

Table I (con’t)

Inorganic Zinc	Ameron	Gl-40 Steel Grit	D-6	5.0	10-Rust 1/8″ Undercut @ Scribe
Chlorinated Rubber			2015	2.0	8-Chalk @ 1 Year 55% Loss of Gloss @ 1 Year
Chlorinated Rubber		Mineral Sand	2029	1.8	lo-Rust 1/16″ undercut @ Scribe
Chlorinated Rubber			2029	3.0	8-Chalk 70% Loss of Gloss @ 1 Year
Inorganic Zinc	Carboline	GL-40 Steel Grit	Czll	6.0	Failed @ 45 Months- Topcoat Delamination.
Vinyl copolymer Tiecoat			935TC	2.0	81% Loss of Gloss @ 1 Year. 6-Chalk @ 1 Year.
Vinyl Copolymer			938	1.5	
Vinyl **Copolymer**		Mineral Sand	938	4.0	Railed @ 45 Months- Topcoat **Delamination.** 81% **LOSS of Gloss** @ **1** Year. 6-Chalk @ 1 Year.
Inorganic Zinc	Carboline	GL-40 Steel Grit	Czl1	3.0	10-Rust 1/16″ Undercut @ Scribe.
Polyamide Epoxy			191HB	6.2	8–Chalk @ 1 Year. 77% Loss of Gloss @ 1 Year.
Mod. Medium Oil Alkyd			GP-62	1.8	
Mod. Medium Oil Alkyd			GP-62	0.8	
Inorganic Zinc	Carboline	Mineral Sand	Czll	7.8	10-Rust 1/8″ Undercut @ Scribe.
Polyamide Epoxy			191HB	6.2	9-Chalk @ 1 Year. 30% Ioss of Gloss @ 1 Year.
Aliphatic Polyurethane			132	4.0	Checking @ 8 Years.
Aliphatic Polyurethane			132	4.5	Mildew @ 8 Years. 8 Few Blisters.
Inorganic Zinc	Carboline	GL-40 Steel Grit	Czll	6.0	Failed @ 24 Months- Topcoat Delamination.
Chlorinated Rubber			3630	2.1	95% Loss of Gloss @ 1 Year
Chlorinated Rubber			3630	0.5	6-Chalk @ 1 Year.
Chlorinated **Rubber**		Mineral Sand	3630	3.0	Failed @ 24 Months– Topcoat **Delamination.** 95% Loss of Gloss @ 1 Year 6-Chalk @ 1 Year.

Table I (con't)

Inorganic Zinc	Devoe	GL-40 Steel Grit	304	5.0	10-Rust 1/16" Undercut @ Scribe.
Vinyl TieCoat.			MD4368	- 0.8	9-Chalk @ 1 Year. 6% Loss of Gloss @ **1**
Vinyl Acrylic			MD4361	1.0	Year. 64% @ 2 **Years.** Cracking @ 10 Years.
Vinyl Acrylic		Mineral Sand	MD4361	3.0	10-Rust 1/8" undercut @ scribe 9-Chalk @ 1 Year. 3% Loss of Gloss @ 1 Year. 60% @ 2 **Years**
Inorganic Ziic	Devoe	GL-40 Steel Grit	304	7.0	10-Rust 4-Chalk
Polyamide Epoxy			224	7.8	4–Erosion @ 6 Years 88% Loss of Gloss @ 2 Months. Pinholes From Topcoat Erosion.
Inorganic Zinc	Devoe	Mineral Sand	304	6.0	Complete Failure of Topcoat @ 8 **years.**
Polyamide Epoxy			224	7.0	Checking @ 6 Years. 10-Rust. Inorganic
Silicone Alkyd			MD3925	4.0	Primer stil1 providing protection.
Silicone Alkyd			MD3925	8.9	
Inorganic Zinc	Devoe	GL-40 Steel Grit	304	5.0	lo-Rust 8-Chalk @ 1 Year
Polyamide Epoxy			224	8.0	96% Loss of Gloss @ 10 Months. Some Under-
Acrylic Expoy		Mineral Sand	229	8.0	cutting @ scribe & Pinholes from Erosion. Checking @ 8 Years. Mildew @ 10 Years.
Inorganic Zinc	Hempel	GL-40 Steel Grit	1570	3.6	10-Rust 1/8" Undercut @ Scribe.
Polyamide Epoxy			HB4520	3.0	2-Chalk @ 9 Months. 96% Loss of **G1oss** @ 4
Polyamide Epoxy			5534	3.8	Months. Erosion-Prtir visible through topcoat @ 10 YR
Inorganic Zinc	Hempel	GL-40 Steel Grit	1570	3.6	9-Rust 8-Chalk @ 1 Year
Polyamide Epoxy			HB4520	3.5	84% **LOSS** of Gloss @ 7 Months.
Alkyd			5214	3.5	Checking @ 8 Years. Mildew @ 10 Years.

Table I(con't)

Inorganic Zinc Polyamide Epoxy Silicone Aluminum (High Heat)	Hempel	GL-40 Steel Grit	1570 HB4520 5372	3.6 3.8 3.0	lo-Rust 1/16" Undercut @ Strike. 9-Chalk @ 1 Year. 31% Loss of Gloss @ 1 Year.
Inorganic Zinc Vinyl TieCoat Vinyl Topcoat	Imperial	GL-40 Steel Grit	555 777 321	5.3 3.4 3.0	l0-Rust 1/16" Undercut @ Scribe. Blisters-6 Few @ 20 Months. Topcoat Delam- initiated @ 10 Years. 8-Chalk @ 1 Year. Flat finish- Gloss not evaluated.
Inorganic Zinc Polyamide Epoxy	Imperial	GL-40 Steel Grit	555 1200	5.0 6.8	10-Rust 4-Chalk @ 9 Months 1/4" Undercut @ scribe Flat finish-Gloss not evaluated.
Inorganic Zinc Polyamide Epoxy Alkyd	Imperial	GL-40 Steel Grit	555 1200 88	4.2 9.6 5.2	lo-Rust 1/16" Undercut @ Scribe. 6-Chalk @ 1 Year. 70% Loss of Gloss @ 1 Year.
Inorganic Zinc Polyamide Epoxy Silicone Al&d	Imperial	GL-40 Steel Grit	555 1200 84	4.5	l0-Rust 1/16" Undercut @ Scribe. 8-Chalk @ 1 Year. 60% Loss of Gloss @ 1 Year. No gloss change 2nd Year.
Inorganic zinc Polyamide Epoxy Aliphatic Polyurethane	Imperial	GL-40 Steel Grit	555 1200 1001	4.4 5.4 2.1	10-Rust 9.5-Chalk @ 1 Year 1/8" Undercut @ Scribe 19% Less of Gloss @ 1 Year.
Inorganic Zinc Vinyl Tiecoat Chlorinated Rubber (Acrylic)	Imperial	GL-40 Steel Grit	555 777 890	4.7 2.9 1.9	lo-Rust 8-Chalk @ 1 Year 1/8" Undercut @ Scribe 49% Loss of Gloss @ lYR Blisters- 6 Few @ 8 YRS Checking @ 10 YRS Topcoat Beginning TO Delaminate. Primer Still providing protection.

Table I (con't)

Inorganic Zinc vinyl Vinyl Acrylic Vinyl Acrylic	International	GL-40 Steel Grit Mineral Sand	2410/11 846 3508 3508	2.0 1.9 1.5 1.0	lo-Rust 8-Chalk @ 1 Year 79% Loss of Gloss @ 1 Year. Checking @ 9 Years. 10-Rust 8-Chalk @ 1 Year 77% Loss of G1oss @ lyr
Inorganic zinc Vinyl Wash Primer Aliphatic Polyurethane Aliphatic Polyurethane	International	GL-40 Steel Grit Mineral Sand	2410/11 1757/58 2202/14 2202/14	2.5 1.0 2.5 3.5	9-Rust 1/2" undercut @ scribe 9-Chalk @ 1 Year 69% Loss of Gloss @ 1 Year. Topcoat began to de-1aminate @ 9 Years. O-Rust (At Failure) 9-Chalk @ 1 Year 72% **Loss** of Gloss @ lyr Topcoat began to delam-innate @ 5 Years, began to peel @ 7 Years, and totally failed @ 10 Yr. No primer visible @ failed area.
Inorganic Zinc Vinyl Wash Primer Aromatic Polyurethane Aromatic Polyurethane	International	GL-40 Steel Grit Mineral Sand	2410/11 1757/58 859 859	2.3 1.0 2.5 2.0	9-Rust 4-Checking. 9-Chalk @ 1 Year 40% Loss of Gloss @ 1 Year. 9–Rust 4-Checking 9-Chalk @ 1 Year. 39% Loss of Gloss @ 1 Year.
Inorganic zinc Polyamide Epoxy	International	GL-40 Steel Grit Mineral Sand	2410/11 8967/ 1539	2.0 16.0	10 Rust-Pinholes from erosion of topcoat. 4-Chalk @ 3 Months. 80% **Loss** of **Gloss** @ 3 Months. lo-Rust 4-Chalk @ 4 Months. 87% **Loss** of **Gloss** @ 3 Months.
Inorganic zinc Vinyl vinyl	Mobile Paint Mfg.	GL-40 Steel Grit	28DH50 5DR5 5DW2	1.8 1.6 2.6	10-Rust 1/8" Undercut @ Scribe 2-Chalk @ 9 Months. Gloss Not Evaluated.

Table I (con 't)

Inorganic Zinc Polyamide Epoxy Polyamide Epoxy	Mobile Paint Mfg.	GL-40 . Steel Grit	28DH50 40AH22 513-17	1.6 6.2 2.7	9-Rust 1/16″ Undercut @ scribe. Checking @ 6 Years. 91% Loss of Gloss @ 1 Year. Topcoat began to delaminate @ 8 Years.
Inorganic Zinc Polyamide Epoxy Alkyd TieCoat Alkyd Topcoat	Mobile Paint Mfg.	GL-40 Steel Grit	28DH50 40AH22 28DR105 5010-16	1.2 6.2 2.7 4.1	8-Rust 9-Chalk @ 1 Year Checking @ 6 Years. 80% Loss of Gloss @ 1 Year. Erosion @ 10 Years.
Inorganic Zinc Polyamide Epoxy Polyvinyl Chloride	Mobile Paint Mfg.	GL-40 Steel Grit	28DH50 40AH20 5DW2	1.2 6.3 4.2	10-Rust Topcoat Delaminated @ 44 Months. Topccat Applied in Error. Checking of Intermedicoat @ 10 Years.
Inorganic zinc Chlorinated Rubber Chlorinated Rubber	Mombile Paint Mfg.	GL-40 Steel Grit	28DH50 548-16 548-16	1.1 2.0 3.5	10-Rust 1/16″ Undercut @ Scribe 5-Chalk @ 1 Year Gloss not evaluated, flat finish. Checking @ 6 Years.
Inorganic Zinc vinyl Vinyl Vinyl	Mobil	GL-40 Steel Grit Mineral Sand	13F12 80R8 83F34 80F34	2.2 0.7 5.3 3.2	lo-Rust 1/4″ Undercut @ Scribe 4-Chalk @ 1 Year. 90% Loss of Gloss @ 9 Months. 10-Rust 4-Chalk @ 1 Year. 90% Ioss of Gloss @ 9 Months.
Inorganic Zinc Polyamide Epoxy Polyamide EPoxY	Nobil	GL-40 Steel Grit Mineral Sand	13F12 89Fl2 84F34	2.5 6.5 1.6	lo-Rust Erosion of ‘I@cOat 4-Chalk @ 5 Months. 90% loss of Gloss @ 4 Months. 10-Rust 4-Chalk @ 5 Months. 91% Loss of Gloss @ 4 Months.

Table I (con't)

Inorganic Zinc	Mobil	GL-40 Steel Grit	" 13F12	2.5	lo-Rust 9-Chalk @ 1 Year.
Polyamide Epoxy			89F15	9.0	7~% Lass of Gloss @ 1 Year.
Alkyd		Mineral Sand	20F34	1.5	lo-Rust 8-Chalk @ 1 Year. 68% Loss of Gloss @ 1 Year.
Inorganic zinc	Mobil	GL-40 Steel Grit	13F12	2.4	10-Rust 9-Chalk @ 1 Year.
Polyamide Epoxy			89F15	9.2	40% Ioss of Glcss @ 1 Year.
Aliphatic Polyurethane		Mineral Sand	40W9	2.8	10-Rust 8-Chalk @ 1 Year. 40% Loss of Gloss @ 1 YR
Inorganic Zinc	Mobil	GL-40 Steel Grit	13F12	2.0	10-Rust 9-Chalk @ 1 Year.
Polyamide **Epoxy**			89F15	8.3	46% Loss of **Gloss** @ **1** Year.
Water Borne Acrylic		Mineral Sand	42F34	1.5	10-Rust 9- Chalk @ 1 Year. 46% **loss** of **Gloss** @ **1** Year.
Inorganic Zinc	Mobil	GI-40 Steel Grit	13F12	2.2	Topcoat Failed @ 6 YRS. Total Failure @ 9 YRS.
Chlorinated Rubber			27F15	4.0	No Primer Visible. 9-Chalk @ 1 Year.
Chlorinated Rubber			28F34	2.8	71% Loss of Gloss @ 1 Year.
		Mineral Sand			lo-Rust Topcoat blistering but not peeling. 8-Chalk @ 1 Year. 70% Loss of Gloss @ 1 year.
Inorganic Zinc	Napko	GL-40 Steel Grit	1375	4.7	10-Rust 1/8" Undercut @ scribe
Copolymer Tiecoat			1340	1.8	9-Chalk @ 1 Year. Gloss not evaluatd,
Vinyl Topcoat			5452	2.8	flat finish.
Inorganic Zinc	Napko	GI-40 Steel Grit	1375	4.5	lo-Rust 9-Chalk @ 1 Year.
Vinyl			5437	2.3	Gloss not evaluated,
Vinyl			5452	2.3	flat finish.

Table I (con't)

Inorganic Zinc	Napko	GL-40 Steel Grit	1375	5.5	8-Rust 1/4" Undercut @ Scribe.
Catalyzed Epoxy			5802	5.2	4-Chalk @ 7 M0nths. 81% **Loss** of Gloss @ 2 Months. Pinholes @ 9 Years.
Inorganic Zinc	Napko	GL-40 Steel Grit	1375	4.9	10-Rust 1/8" Undercut @ Scribe.
Polyamide Epoxy			5616	2.4	8-Chalk @ 1 Year. 90% Loss of Gloss @
Alkyd			4318	1.0	9 Months.
Inorganic zinc	Napko	GL-40 Steel Grit	1375	5.8	7-Rust 1/4" Undercut @ Scribe
Chlorinated Rubber			8-4137	3.0	9-Chalk @ 1 Year. 74% Loss of Gloss @
Chlorinated Rubber			8-4137	2.6	1 Year. Topcoat began to de-laminate @ 9 Years, and to peel @ 10 Years. No primer visible @ detached area.
~organic Zinc	Napko	GL-40 Steel Grit	1375	5.7	lo-Rust 1/4" Undercut @ Scribe
Polyamide Epoxy			5616	1.6	9.5-Chalk @ 1 Year. 15% Loss of Gloss @
Polyurethane			5909	2.5	1 Year.
Inorganic Zinc	Napko	GW40 Steel Grit	1375	5.4	Topcoat Delaminated from Inorganic Zinc
High Build Polyurethane			8-4144	3.4	@ 18 Months. 9.5-Chalk @ 1 Year.
Polyurethane			5909	3.5	17% Loss of Gloss @ lyr
Inorganic Zinc	Porter	GL-40 Steel Grit	351	3.0	lo-Rust 2-Chalk @ 9 Months.
Vinyl Wash Primer			1799	0.5	Gloss not evaluated, flat finish.
vinyl			3710	2.0	
Inorganic Zinc	Porter	Mineral Sand	351	3.0	lo-Rust 1/8" Undercut @ Scribe.
Vinyl Wash Primer			1799	0.5	9.5-Chalk @ 1 Year. 23% **Loss** of **Gloss** @
Aliphatic Polyurethane			4674	2.0	1 Year.

Table I (con't)

Inorganic Zhc High Build vinyl	Sherwin-Williams	GL-40 Steel Grit	A6181/B69 B69A26	(Total DFT)	8-Rust 1/16" Undercut @ Scribe 6-Chalk @ 1 Year. Flat finish.
Inorganic Zinc Epoxy	sherwin-Williams	GL-40 Steel Grit	A6181/k69 B69w70	7.7 (Total DFT)	8-Rust 1/3" Undercut @ Scribe 4-Chalk @ 7 Months. 91% Loss of Gloss @ 2 Months.
Inorganic Zinc Epoxy Alkyd	Sherwin-Williams	GL-40 Steel Grit	A6181/B69 B69N70 B53W10	11.5 (Total DFT)	Bottom 1/2 Panel Totally Failed. No Primer Visible. 6-Chalk @ 1 Year. 89% **Loss** of Gloss @ 7 Nbnths.
Inorganic Zinc Epoxy Aliphatic Polyurethane	Sherwin-Williams	GL-40 Steel Grit	A6181/B69 B69N70 F63w13	- 14 (Total DFT)	9-Rust 1 1/2" Undercut @ 8-Chalk @ 1 Year. 62% **Loss** of Gloss @ 1 Year. **Moss** @ 8 years.
Inorganic zinc Chlorinated Rubber Chlorinated Rubber	Sherwin-Williams	GL-40 Steel Grit	A6181/B69 B69W17 B69W17	8.5 (Total DFT)	8-Rust 1/8" Undercut @ Scribe. 9-Chalk @ 1 Year. 67% **loss** of **Gloss** @ 1 Year. Topcoat beginning to fail @ 10 Years.
Modified Inorganic Zinc Polyamide Epoxy Polyamide Epoxy	Sigma	GL-40 Steel Grit	7552 7430/ 2190 7425/ 7000	2.3 5.1 3.6	10-Rust Al ligating/Pinholes @ 56 Months. Complete . Topcoat Failed @ 66 Months. 2-Chalk @ 5 Months. 95% loss of Glcss @ 5 Months.
Modified Inorganic zinc Polyamide Epoxy Silicone Alkyd	Sigma	GL-40 Steel Grit	7552 7430/ 2190 7238/ 7000	2.3 6.6 0.7	lo-Rust 1/32" Undercut @ Scribe 9-Chalk @ 1 Year. 56% **loss** of Glcss @ 1 Year. Checking @ 8 Years.

Table I (con’t)

Modified Inorganic Zinc	Sigma	GL-40 Steel Grit	7552	2.6	9-Rust 4-checking 9.5-Chalk @ 1 Year.
Polyamide m w			7430/ 2190	7.4	7% loss of Gloss @ 1 Year.
Aliphatic Polyurethane			7520/ 7000	1.9	Topcoat beginning to fail @ 10 Years.
Modified Inorganic Zinc	Sigma	GL-40 Steel Grit	7552	2.5	10-Rust 1/16″ Undercut @ Scribe. 8-chalk @ 1 Year.
Chlorinated Rubber			7311/ 200	3.5	60% **loss Of G1oss** @ 1 Year.
Chlorinated Rubber			7310/ 200	3.4	4-Checking @ 6 Years.

2.1.5. Exterior Generic Coating System Test Results

As stated earlier, Table I contains a summary of the results of of the various generic coating systems applied over inorganic zinc primers. Table III contains a summary of the failure modes of each coating system. Figures 2.1 thru 2.7 contain photographs of representative test panels. As seen from the test data, differences in chalking and percent change in gloss are easily detected. These results generally agree with other published test results. Epoxies chalk more than chlorinated rubbers and chlorinated rubbers chalk **more than aliphatic polyurethanes.**

2.1.5.1 Corrosion Protection

Most of the systems tested continue to provide adequate corrosion protection as concerns overall ASTM Rust Grades. Table II contains a summary of the degree of undercutting at the scribe of **each** generic coating type. See Figure 2.2 for an example of undercutting. Except for the chlorinated rubber systems, the degree of undercutting is basically the same for the balance of generic types. In all cases, the chlorinated rubber systems had some degree of undercutting.

FIGURE 2.2: UNDERCUTTING AT THE SCRIBE

Table II: Summary of Undercutting

System	Undercutting	Percent of Systems With Undercutting
Inorganic Zinc Epoxy	5 of 8 Systems Tested	68%
Inorganic Zinc Epoxy/Alkyd	3 of 6 Systems Tested	50%
Inorganic Zinc Epoxy Polyurethane	5 of 7 Systems Tested	71%
Inorganic Zinc Vinyl	6 of 9 Systems Tested	67%
Inorganic Zinc Chlorinated Rubber	6 of 6 Systems Tested	100%

One interesting point was observed concerning the mechanism of total system failure. In some cases, the intermediate and topcoat would fail and leave the inorganic zinc primer intact. The intact primer, once exposed, continued to provide corrosion protection to the steel substrate. In other cases, no inorganic zinc remains after failures of the topcoats. Many times this phenomenon is proceeded by what appears to be blistering of the topcoat. Once the topcoat ruptures, a fine, white powder is visible under the coating which is easily removed by subsequent rain leaving a bare substrate to rust. This could be the result of the formation of an oxygen deficient corrosion cell at the topcoat and primer interface caused by slow permeation of water through the film. This water, with time, possibly results in the formation of zinc hydroxide which disolves the zinc primer further accelerating the deterioration of coating system. (See Figure 2.3).

The failure of the inorganic zinc primer simultaneous with the topcoat(s) is not limited to a specific generic type of topcoat system nor is it related a specific manufacturer. Five systems failed by this mechanism. These include three chlorinated rubber systems, one epoxy intermediate/alkyd topcoat and one vinyl wash primer/aliphatic polyurethane system. Four systems failed with the inorganic zinc primer still intact and providing protection to the substrate. These included one chlorinated rubber, one epoxy, one epoxy plus silicone alkyd and one vinyl system.

FIGURE 2.3: TOPCOAT FAILURES WITH\WITHOUT PRIMER STILL PRESENT

2.1.5.2 Overall System Performance

2.1.5.2.1 **Epoxy Intermediate with** Alkyd and Silicone Alkyd Topcoat

The Primary failure **mode of the silicone alkyd system was checking. Three of the four tested systems had some** degree of checking at eight years with one system at six years. The straight alkyd systems failed by either checking (one example), erosion (one example) or total delamination (one example). All but one of the systems (there were a total of eleven) continued to provide protection to the substrate. See Figure 2.4 for example of checking.

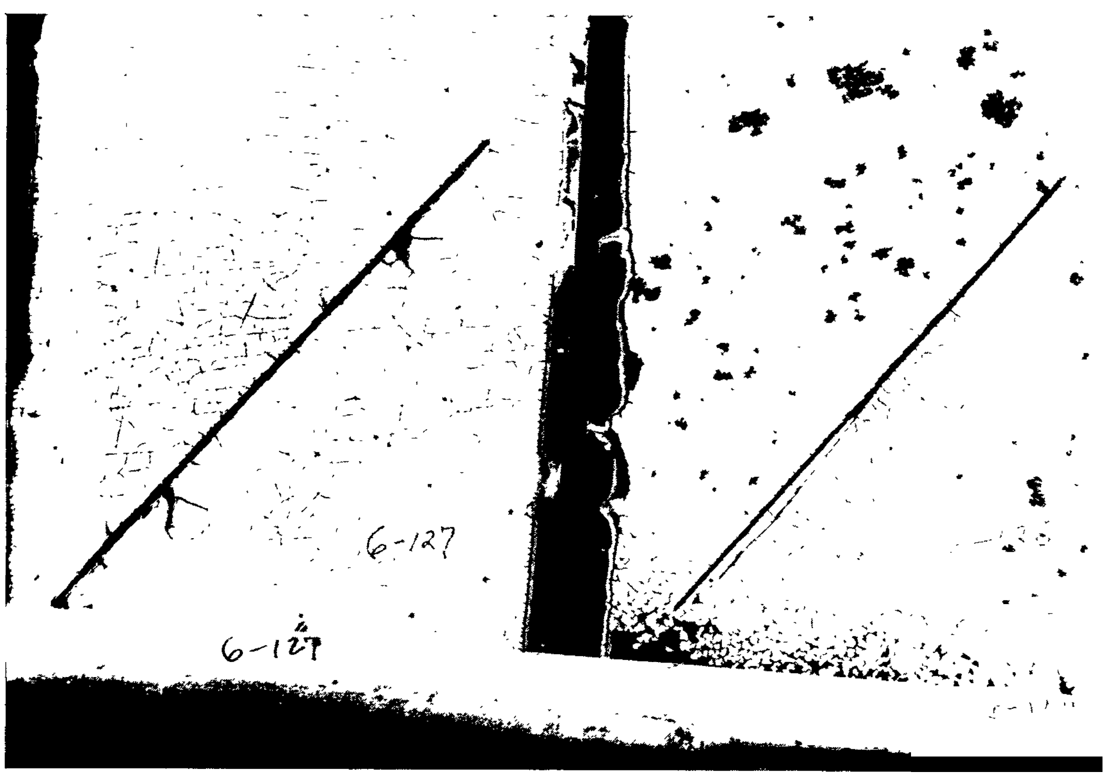

FIGURE 2.4: CHECKING

2.1.5.2.2 Chlorinated Rubber Systems

Of the systems tested, the chlorinated rubber systems demonstrated the poorest overall performance. In addition to the undercutting at the scribe noted in the above paragraphs, three of the eight systems tested have totally failed, two are beginning to fail by topcoat(s) delamination after ten years and all but one system has some type of defect such as checking or blistering. It can be safely concluded that chlorinated rubber coatings applied over inorganic zinc require a recoat maintenance period of from two to six years. This confirms the Japanese practice of recoating at approximate four years intervals due to a loss of plasticizers. (See reference 4) Figure 2.5 is a graphic example of the performance of a chlorinated rubber system.

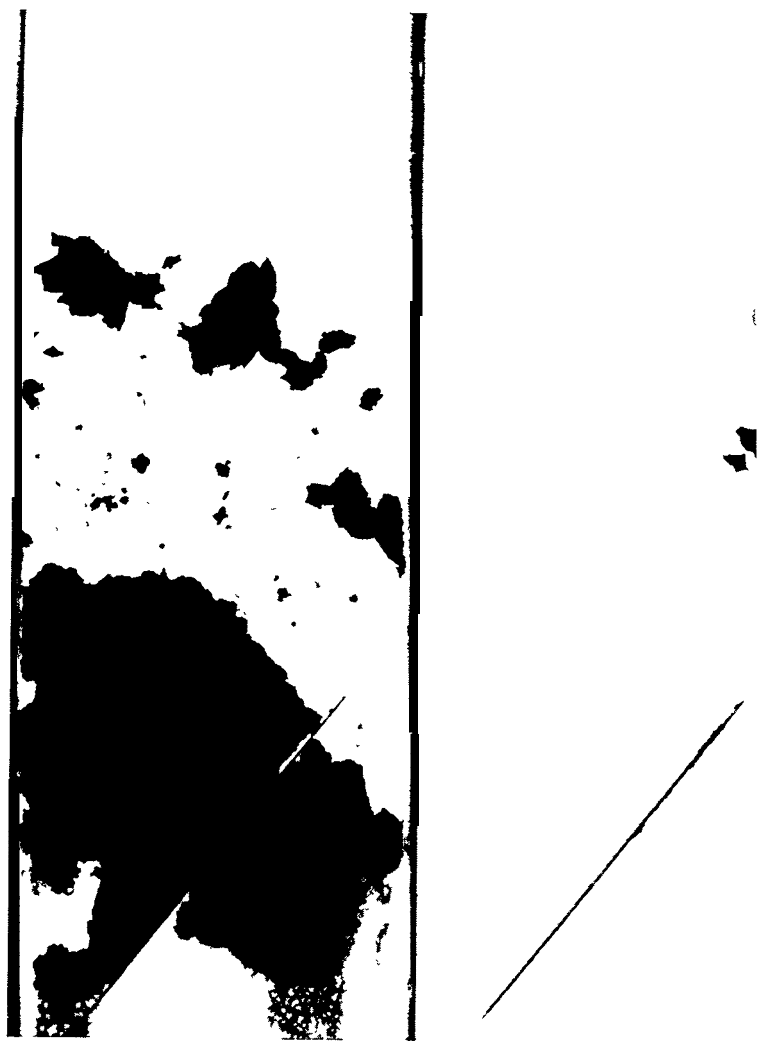

FIGURE 2.5: CHLORINATED RUBBER FAILURES

2.1.5.2.3. Epoxy Systems

As could be expected, the primary failure mode of epoxy topcoats was erosion. The coating chalks in ultraviolet exposure, and the resultant loose chalk is removed by rain. The reduction in film thickness was measured and found to be from 0.3 to 1.2 roils per year. With time, the epoxy topcoats will be removed and leave the inorganic zinc primer exposed. Out of a total of ten systems tested, three of the systems failed by delamination of one or more of the topcoats. Based on the data it would be difficult to predict projected system life. After ten years, seventy percent of the epoxy system continue to provide adequate corrosion protection.

2.1.5.2.4 Vinyl

Four of the nine vinyl systems had some type of failure but all continued to provide protection to the substrate. One failed by delamination of the topcoat but the inorganic zinc primer remained intact. Two failed by checking at nine and ten years respectively, and one was showing signs of blistering at ten years. The blistering could be underfilm deterioration of the inorganic zinc but this was not confirmed (See Figure 2.6).

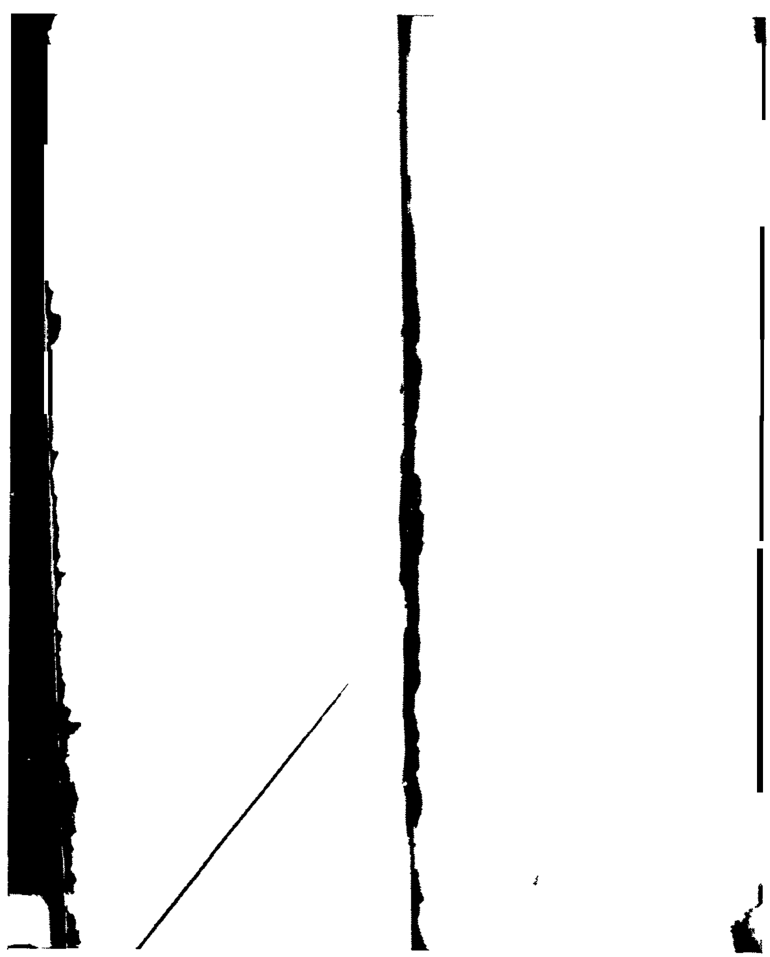

FIGURE 2.6: VINYL BLISTERING

2.1.5.2.5 Ali.phatic Polyurethanes

None of the seven polyurethane systems failed during the test period. Two systems did start to check; one at eight years and another at ten years. Undercutting may have been somewhat worse but not statistically significant. See Figure for an example of aliphatic polyurethane performance.

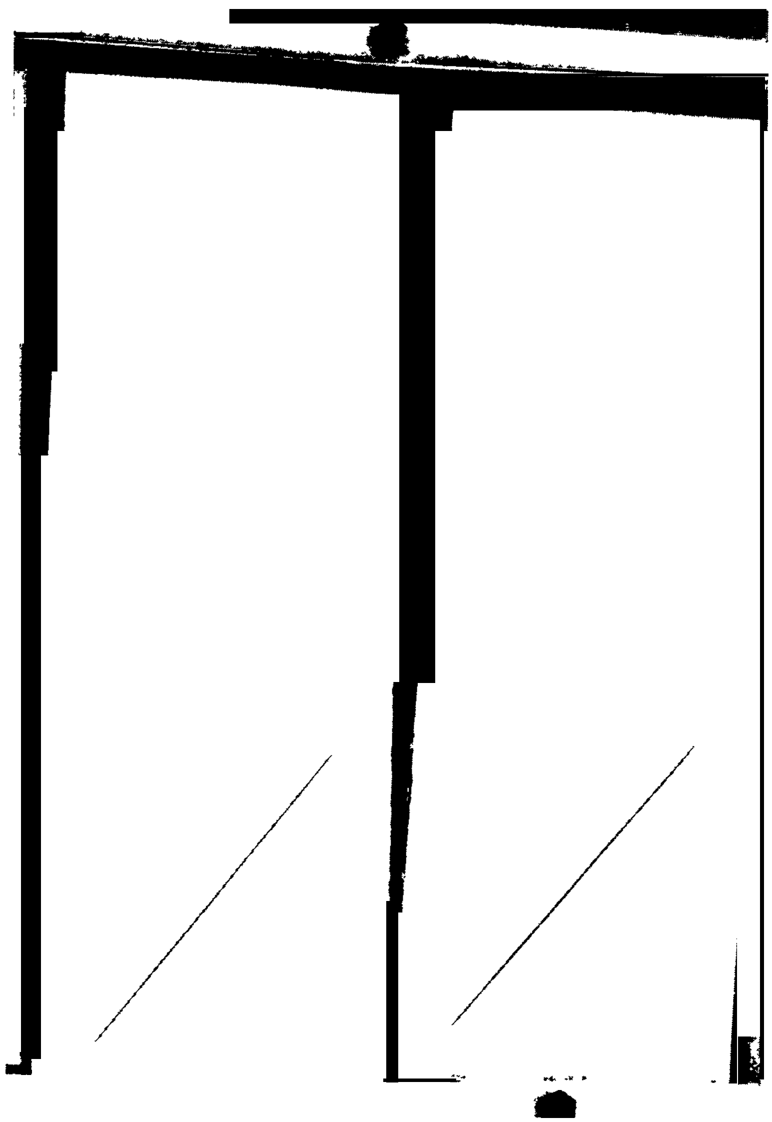

FIGURE 2.7: EPOXY/ALIPHATIC POLYURETHANE SYSTEM

Table III: Total System Failure Modes

Generic System	Systems Failed/Tested	Time	Primary Failure Mode
Epoxy/Silicone Alkyd	3 of 4	6 to 8 Years	Checking
Epoxy/Alkyd	3 of 7	6 to 8 Years 10 Years 10 Years	Checking Erosion Total Failure
Vinyl Wash Primer/ Aliphatic Polyurethane	1 of 1	10 Years	Total Failure
High Build Urethane/ Aliphatic Polyurethane	1 of 1	18 Months	Delamination of Topcoat from Primer
Vinyl Wash Primer/ . Aromatic Polyurethane	1 of 1	66 Months	Checking
Epoxy/Aliphatic Polyurethane	0 of 7	10 Years	Checking
Chlorinated Rubber	7 of 8	1@ 24 Months 3@ 9 to 10 Years 2@ 6 Years 1@ 8 Years	Topcoat Delamination Topcoat Failure Checking Blistering
Epoxy	8 of 10	4@ 6 to 10 Years 1@ 8 Years 1@ 9 Years 1@ 5 Years 1@ 10 Years	Erosion Checking/Topcoat Fail Pinholes Topcoat Failure Total Failure of 1/2 Panel
Vinyl	4 of 9	1@ 5 Years 2@ 9 to 10 Years	Topcoat Delamination Checking

*All systems primed with inorganic zinc.

2.2 Citric Acid Cleaned Verses Abrasive Blast Cleaned Panels

There were two different series of exterior test fence exposures of tested primers. The first was a direct comparison of primers applied to both citric acid cleaned panels and abrasive blast cleaned panels. The second was a test to compare citric acid as a touch-up surface preparation technique to the widely used power tool cleaning touch-up technique. The paragraphs which follow discuss each series in detail.

2.2.1 Primer Test

2.2.1.1 Test Panel Preparation

One hundred primers representing seventeen generic types were submitted by ten suppliers. Test panels of A-36 steel measuring 6" X 18" X 1/4" were first descaled and then allowed to rust for approximately eight weeks by exposure in an outside industrial, marine environment. Following aged rusting, the panels were divided into two groups. The first group was abrasive blasted to Steel Structures Surface Preparation Standard, SSPC SP 10, "Near White Blast," and the second group was cleaned utilizing a citric acid process. The selected primers were then applied to panels cleaned by each process. Both panels within a set were sprayed at the same time in an effort to duplicate actual film thicknesses. No inhibitors were used with the citric acid process.

2.2.1.2 Test Environment and Evaluation Technique

The resulting primed panels were then placed on the test fence at 45 degrees South for eight years. Rust grades were determined in accordance with ASTM D610.

2.2.1.3 Primer Test Results

Table VI contains detail application data and performance rating of each primer tested. There was no difference in the performance of the water based self cured and post cure inorganic zincs applied over both surface preparation methods. The remainder of the other types of zinc rich primers also demonstrated almost identical results. Table IV contains a summary of the results for some of the generic types of primers. As stated earlier no attempt should be made to compare performance between primers of the same generic type and different suppliers or different ric types without taking into account the actual film thickness of the applied materials and the design purpose of each material. With the exception of some of the alkyd primers, most of the non zinc pigmented organic primers prepared with both types of surface preparation techniques had failed within eight years. In most cases the panel cleaned by abrasive blasting failed first.

Table IV: Citric Acid/Abrasive Blast Performance Summary

Generic Primer	Average Rust Grade			
	Citric Acid		Abrasive Blast	
	Mean	Mode	Mean	Mode
Alkyl Inorganic Zinc	9.3	10.0	9.2	10.0
One Component Inorganic Zinc	6.8	10.0	5.0	1.0
Water Based Inorganic Zinc	8.3	10.0	8.3	10.0
Post Cured Inorganic Zinc	10.0	10.0	10.0	10.0
One Component Epoxy Zinc Rich	8.0	9.0	8.0	9.0
Two Component Epoxy Zinc Rich	7.6	9.0	7.2	10.0
Alkyd Primer	5.1	8.0	4.1	

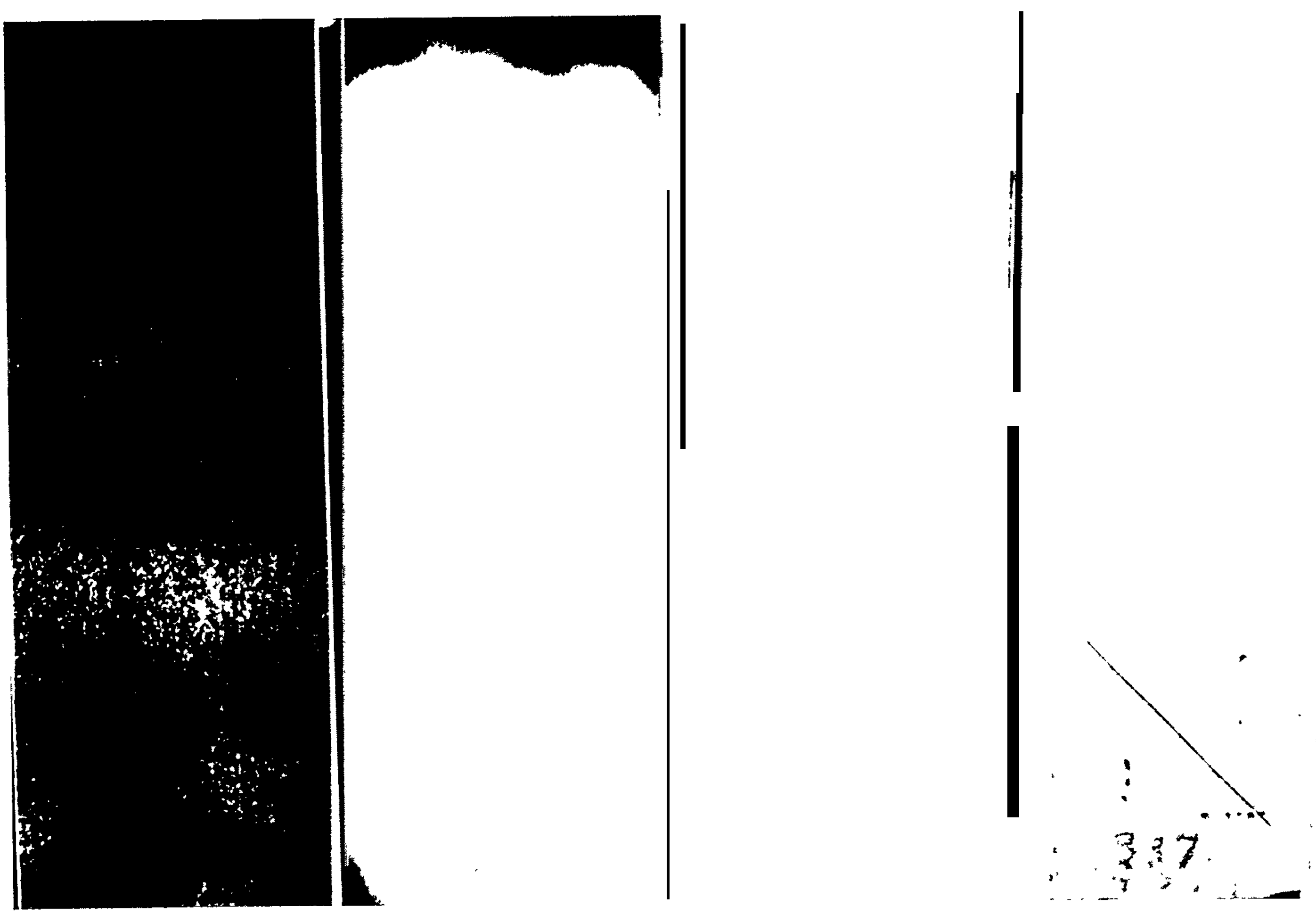

FIGURE 2.8: ABRASIVE(LEFT) VS CITRIC ACID(RIGHT) CLEANED PANELS

TABLE v

Various Generic Primers Applied to Abrasive Blast Cleaned and Citric Acid Cleaned Panels After Eight Years Exposure Exterior Test Rack (45 Degrees S)

GENERIC TYPE	SUPPLIER	PRODUCT No.	SURFACE PREPARATION	FILM THICKNESS	RUST GRADE
Alkyl Inorganic Zinc	Ameron	D-9	Abrasive Blast	4.8	10
Solvent Base			Citric Acid	4.8	10
Alkyl Inorganic Zinc	Byco	101	Abrasive Blast	2.8	7
Solvent Ease			Citric Acid	2.4	7
Al&l Inorganic Zinc	Carboline	Czll	Abrasive Blast	4.2	10
Solvent Ease			Citric Acid	4.2	10
Alkyl Inorganic Zinc	Carboline	CWll	Abrasive Blast	1.6	Failed 32Mo
Solvent Ease			Citric Acid	1.4	10 @ 32Mo
Alkyl Inorganic Zinc	Devoe	304	Abrasive Blast	2.6	9
Solvent Base			Citric Acid	2.6	9
Alkyl Inorganic Zinc	Parboil	114	Abrasive Blast	3.0	10
Solvent Base			Citric Acid	2.7	10
Alkyl Inorganic Zinc	Imperial	555	Abrasive Blast	3.0	10
Solvent Ease			Citric Acid	2.7	10
Alkyl Inorganic Zinc	International	QHA027/	Abrasive Blast	4.6	10
Solvent Ease		QHA028	Citric Acid	4.7	10
AlkylInorganic Zinc	Mobil	13F12	Abrasive Blast	1.8	6
Solvent Ease			Citric Acid	1.6	7
Alkyl Inorganic Zinc	Napko	1375	Abrasive Blast	4.1	10
Solvent Base			Citric Acid	4.2	10
Alkvl Inoraanic Zinc	Porter	351	Abrasive Blast	2.2	10
Sol&nt E&e			Citric Acid	2.1	10
Modified Alkyl	Devoe	302R	Abrasive Blast	3.2	Failed 7 Yr
Inorqanic Zinc			Citric Acid	3.0	Failed 8 Yr
One Component	Amsron	160	Abrasive Blast	3.2	8
Inorqanic Zinc			Citric Acid	3.2	10
One Component	Ameron	2155	Abrasive Blast	4.1	Failed 8 Yr
Inorqanic Zinc			Citric Acid	3.6	10
One Component	Byco	102SP92	Abrasive Blast	6.8	10
Inorqanic Zinc			Citric Acid	6.5	10
One Component	Devoe	306	Abrasive Blast	3.8	Failed 7 Yr
Inorqanic Zinc			Citric Acid	4.0	Failed 8 Yr
One Ccmponent	Devoe	308	Abrasive Blast	1.7	Failed 18Mo
Inorganic Zinc			Citric Acid	1.4	8 @ 18 Mo
One Component	Devoe	309	Abrasive Blast	2.6	7
Inorganic Zinc			Citric Acid	2.0	9
One Component	International	NOA200	Abrasive Blast	3.1	Failed 18 Mo
Inorganic Zinc			Citric Acid	3.0	Failed 18 Mo
One Component	Mobil	13G10	Abrasive Blast	2.9	7
Inorganic Zinc			Citric Acid	2.4	10
One Component	Napko	1301	Abrasive Blast	6.0	9
Inorganic Zinc			Citric Acid	5.4	9
Water Based, Self	Ameron	D-4	Abrasive Blast	4.1	10
Cure, Inorqanic Zinc			Citric Acid	4.1	10

Table V (con't)

GENERIC TYPE	SUPPLIER	PRODUCT NO.	SURFACE PREPARATION	FILM THICKNESS	RUST GRADE
Water Based, Self Cure, Inorganic Zinc	Devoe	305	Abrasive Blast	4.3	10
			Citric Acid	3.5	10
Water Based, Self Cure, Inorganic Zinc	Farboil	76	Abrasive Blast	5.0	10
			Citric Acid	4.5	10
Water Based,Self Cure, Inorganic Zinc	International	TQA001/ TQA002	Abrasive Blast	3.1	9
			Citric Acid	3.0	9
Water Based, Self Cure, Inorganic Zinc	Mobil	46F1	Abrasive Blast	4.3	Failed 3 Mo
			Citric Acid	3.8	Failed 6 Yr
Water Based ,Self Cure, Inorganic Zinc	Napko	1371	Abrasive Blast	5.1	10
			Citric Acid	5.3	10
Post Cure, Inorganic Zinc	Ameron	D-3	Abrasive Blast	4.6	10
			Citric Acid	4.3	10
Post Cure, Inorganic Zinc	Napko	1361	Abrasive Blast	3.3	10
			Citric Acid	3.1	10
One Component Epoxy Zinc Rich	Byco	150-1	Abrasive Blast	4.1	9
			Citric Acid	3.6	9
One Component Epoxy Zinc Rich	Imperial	512	Abrasive Blast	3.6	9
			Citric Acid	2.9	9
One Component Epoxy Zinc Rich	International	ETA441	Abrasive Blast	3.0	Failed 3 Mo
			Citric Acid	2.8	5 @ 3 m
One Component Epoxy Zinc Rich	Mobil	518F208	Abrasive Blast	4.0	10
			Citric Acid	2.9	9
One Component Epoxy Zinc Rich	Napko	1355	Abrasive Blast	9.4	9
			Citric Acid	9.2	10
One Component Epoxy Zinc Rich	Porter	309	Abrasive Blast	3.4	10
			Citric Acid	3.3	10
Two Component Epoxy Zinc Rich	Byco	150-5	Abrasive Blast	4.5	9
			Citric Acid	4.3	9
TWO Component Epoxy Zinc Rich	Farboil	28	Abrasive Blast	2.4	Failed 32 Mo
			Citric Acid	2.3	Failed 7 Yr
TWO Component Epoxy Zinc Rich	Mobil	13F4	Abrasive Blast	2.4	6
			Citric Acid	2.3	9
TWO Component Epoxy Zinc Rich	Napko	5614	Abrasive Blast	5.5	9
			Citric Acid	5.4	10
Two Component Epoxy Zinc Rich	Porter	308	Abrasive Blast	3.8	10
			Citric Acid	3.6	10
Organic Zinc, Chlorinated Rubber	Byco	150-7	Abrasive Blast	3.7	8
			Citric Acid	3.7	7
Organic Zinc	Farboil	79 (Mil-P-1048)	Abrasive Blast	3.9	10
			Citric Acid	3.9	10
One Component Epoxy Primer	Byco	150-2	Abrasive Blast	1.7	Failed 5 Mo
			Citric Acid	1.2	Failed 5 Mo
One Component Epoxy Primer	Farboil	1E2546	Abrasive Blast	1.7	Failed 3 Mo
			Citric Acid	1.3	Failed 3 Mo
One Component Epoxy Primer	Imperial	1215	Abrasive Blast	2.3	Failed 13 Mo
			Citric Acid	1.9	4@13 Mo
One Component Epoxy Primer	International	NEA200	Abrasive Blast	2.8	Failed 6 Yr
			Citric Acid	2.6	Failed 6 Yr

TABLE V(con't)

GENERIC TYPE	SUPPLIER	PRODUCT NO.	SURFACE PREPARATION	FILM THICKNESS	RUST GRADE
One Component	Napko	1340	Abrasive Blast	2.6	9
Epoxy Primer			Citric Acid	2.6	10
Polyamide	Wren	71	Abrasive Blast	3.2	6
Epoxy			Citric Acid	2.9	7
Polyamide	Carboline	193	Abrasive Blast	4.0	Failed 66 M0
Epoxy			Citric Acid	3.8	Failed 66 Mo
Polyamide	Devoe	202	Abrasive Blast	2.0	Failed 7 Yr
Eooxv			Citric Acid	2.2	Failed 7 Yr
Polyamide	Devoe	208	Abrasive Blast	2.1	Failed 7 Yr
Epoxy			Citric Acid	1.8	Failed 32 Mo
Polyamide	Devce	230FD	Abrasive-Blast	6.1	8
Epoxy			Citric Acid	5.4	7
Polyamide	Farboil	4202	Abrasive Blast	2.0	Failed 13 Mo
Epoxy			Citric Acid	1.8	5 @ 13 Mo
Polymide	Farboil	NAVY	Abrasive Blast	3.9	Failed 7 Yr
Epoxy		For - 150	Citric Acid	3.4	Failed 7 Yr
Polyamide	Imperial	1219	Abrasive Blast	5.7	Failed 7 Yr
Epoxy			Citric Acid	5.3	Failed 7 Yr
Polyamide	International	EPA0061\	Abrasive-Blast	3.9	Failed 32Mo
Epoxy		EBA744	Citric Acid	3.7	7@32Mo
Polyamide	Mobil	65Tl\	Abrasive-Blast	4.0	Failed 32Mo
Epoxy		65F15B	Citric Acid	3.6	Failed 32Mo
Polyamide	Napko	5616	Abrasive Blast	2.0	Failed 7 Yr
Epoxy			Citric Acid	2.2	Failed 7 Yr
Polyamide	Porter	4300	Abrasive Blast	2.2	Failed 7 W
Epoxy		MCR43	Citric Acid	2.4	Failed7 Yr
Polyamide	Porter	24770	Abrasive Blast	2.5	Failed 7 Yr
Epoxy			Citric Acid	2.8	Failed 7 Yr
Polyamine	Mobil	71F84B\	Abrasive Blast	2.6	Failed 32M0
Epoxy		71T1	Citric Acid	2.7	Failed 32Mo
E@xy Ester	Byco	360-l	Abrasive Blast	3.2	9
			Citric Acid	3.1	10
Epoxy Ester	Farboil	8229	Abrasive Blast	1.8	Failed 32Mo
			Citric Acid	2.2	6@32Mo
Alkyd	Byco	400-2	Abrasive Blast	2.5	6
			Citric Acid	2.5	8
Alkyd	Farboil	1253	Abrasive Blast	3.3	Failed 7 W
			Citric Acid	3.0	Failed 7 Yr
Alkyd	Farboil	6031	Abrasive Blast	2.3	4
			Citric Acid	2.1	7
Alkyd	Imperial	62	Abrasive Blast	2.9	7
			Citric Acid	2.7	8
Alkyd	International	CPA476	Abrasive Blast	2.4	6
			Citric Acid	2.2	7
Alkyd	Mobil	53R1	Abrasive Blast	2.8	Failed 6 Yr
			Citric Acid	2.8	Failed 6 Yr
Alkyd	Napko	1313	Abrasive Blast	2.7	7
			Citric Acid	3.0	8
Alkyd	Porter	297	Abrasive Blast	2.5	Failed 7 Yr
			Citric Acid	2.6	Failed 7 Yr

TABLE V(con,t)

GENERIC TYPE	SUPPLIER	PRODUCT NO.	SURFACE PREPARATION	FILM THICKNESS	RUST GRADE
vinyl	Ameron	86	Abrasive Blast	1.6	Failed 4 Mo
			Citric Acid	1.0	Failed 4 Mo
vinyl	Ameron	33	Abrasive Blast	2.4	Failed 7 Mo
			Citric Acid	2.0	Failed 7 Mo
vinyl	Byco	600-2	Abrasive Blast	2.2	Failed 7 Yr
			Citric Acid	1.7	Failed 7 Yr
Vinyl	Carboline	8HB	Abrasive Blast	2.8	Failed 32 MO
			Citric Acid	2.9	6 @ 32MO
Vinyl	International	VXLOOO	Abrasive Blast	3.3	10
			Citric Acid	3.0	10
Vinyl Wash Primer	Porter	VC17	Abrasive Blast	1.2	Failed 3 Mo
			Citric Acid	0.9	Failed 3 Mo
Chlorinate Rubber	Carboline	3631	Abrasive Blast	2.3	Failed 7 Yr
			Citric Acid	2.4	Failed 7 Yr
Chlorinated Rubber	Devoe	MD3500	Abrasive Blast	1.7	Failed 13 Mo
			Citric Acid	1.6	Failed 13 MO
Chlorinated Rubber	Farboil	58ACG	Abrasive Blast	1.9	Failed 32 MO
			Citric Acid	1.6	Failed 32 Mo
Chlorinated Rubber	Imperial	880	Abrasive Blast	4.8	6
			Citric Acid	5.0	4
Chlorinated Rub&r	International	LPA300	Abrasive Blast	2.8	Failed 7 Yr
			Citric Acid	2.8	Failed 7 Yr
Chlorinated Rubber	Bbbil	67F34	Abrasive Blast	3.9	8
			Citric Acid	4.2	8
Chlorinated Rubber	Napko	5202	Abrasive Blast	4.2	Failed 7 Yr
			Citric Acid	4.1	Failed 7 Yr
Ketamine Epoxy	Devoe	244HS	Abrasive Blast	3.7	Failed 7 Yr
			Citric Acid	3.3	Failed 7 Yr
Bituminous	Devoe	4314	Abrasive Blast	2.5	Failed 13 Mo
			Citric Acid	2.3	Failed 13 Mo
Bituminous	International	JAA021	Abrasive Blast	3.8	9
			Citric Acid	3.6	10
Phenolic-Vinyl	International	NFA081	Abrasive Blast	2.1	Failed 8 Yr
			Citric Acid	2.1	Failed 8 Yr
Water Borne (Emulsion)	Byco	500-1	Abrasive Blast	2.4	Failed 7 Mo
			Citric Acid	2.1	Failed 7 Mo
Water Borne (Emulsion)	Farboil	8285	Abrasive Blast	3.1	Failed 32 Mo
			Citric Acid	3.1	Failed 32 MO

2.3 Touch-up Surface Preparation Test

2.3.1 Test Panel Preparation

Twenty different primers representing twelve generic types were selected for the touch-up surface preparation test. The test panels were 6" X 18" X 1/4", A-36 steel panels which were first abrasive blasted to Steel Structure Painting Council Surface Preparation Standard SSPC SP 10, "Near White Blast" and then primed. **Each primer selected was applied to the top and bottom third of two each, steel panels. The center third was left bare. Following cure of each coating, a** 3/4" weld was made through a portion of the coating and.into the unpainted **area. The prepared panels were then placed on an exterior test rack at** 45 degrees South for ten weeks and allowed to rust. After the exposure period, the panels were removed from the rack, and one panel from each set was touch-up cleaned using a citric acid spray technique, and one panel from each set was power tool cleaned in accordance with the procedure defined for erection joints in "Catalog of Existing Small Tools for Surface Preparation and Support Equipment for Blasters and Painters." During the citric acid operation it was noted that the citric acid reacted with the alkyl inorganic zinc types of primers (solvent based) and removed the majority of the zinc leaving the panel essentially bare. The water based self cure was removed to a lesser degree and the post cure inorganic zinc was not disturbed. It must also be pointed out that the citric process did not remove residual weld slag or heat damaged initial primer. No attempt was made to supplement the citric acid cleaning with mechanical cleaning prior to touch-up priming. The touched-up panels were preprimed and placed back on the exterior test fence at 45 degrees South for seven and one-half years.

2.3.2 Test Results of Touch-Up (Repair) Panels

Table VI contains a tabulation of the test results. The overall performance of the citric acid touch–up cl caned surfaces was inferior to the power tool touch-up cleaned surfaces. The citric acid cleaned primer failure is due to weld damaged paint. In conclusion, citric acid cleaning for touch–up of damaged weld areas must be supplemented with a mechanical cleaning method to remove residual slag, weld splatter, and damaged paint.

2.4 Comparison of Various Generic Types of Primers

In addition to the observations concerning the comparison between abrasive blast panels and citric acid cleaned panels, several other comparisons of generic types can be drawn. For example, the two component inorganic zincs performed better than al 1 other primers exposed on the test fence. With the exception of one water based , self cured product which failed at three months, and one alkyl silicate inorganic zinc which was applied at less than 2.0 roils dry film thickness, the remainder continued to provide excellent corrosion protection. The film thickness of the alkyl silicate zincs seemed to have a direct influence on the performance. It can also be noted that, of the systems tested, the two component inorganic zinc primers outperformed the organic zinc rich materials. Another interesting finding concerned the one component inorganic zinc primers applied over abrasive blast cleaned panels. Two failed at 18 months and two failed at eight years. The alkyd primers are good performers, surpassing the polyamides epoxies, vinyls and chlorinated rubbers. Of the eight alkyd primers tested, five were still providing some degree of protection after eight years. Only two polyamide epoxies out of thirteen tested were providing protection at this time even though, in most cases, failure did not occur until six years. one vinyl, of five tested, and one chlorinated rubber, of seven tested, still provided some degree of protection. Most of the vinyls and chlorinated rubbers failed within the first three years. The one component epoxy was the worst performer of those tested after 66 months; however, these materials are only designed for 6 to 9 months protection prior to topcoating. It should also be noted that one aluminum pigmented bituminous primer applied 3.8 roils dry has no rust on the citric acid cleaned panel and a rust grade 9 on the abrasive blasted panel .

Table VI: Touch-up Surface Preparation Performance of Various Primers Applied to Either Power Tool Cleaned or Citric Acid Cleaned Prepared Panels After 64 Months

GENERIC TYPE	SUPPLIER	PRODUCT No.	SURFACE PREPARATION	FILM THICKNES	RUST GRADE
Post Cure Inorganic Zinc	Ameron	D-3	Power Tool		
			Citr:		
Water Based, Self Cure Inorganic Zinc	Ameron	D4	Power Tool	2.3	10
			CitricAcid	2.1	
Alkyd Inorganic Zinc&	Carboline	CZ11	Power Tool	4.8	10
			Citric Acid	4.3	10
Alkyd Inorganic Zinc	Mobil	13F12	Power Tool	3.3	10
			Citric Acid	2.7	10
Alkyd Inorganic Zinc	Sigma	711G	Power Tool	4.0	9
			Citric Acid	3.4	9
Alkyd Inorganic Zinc	Mobil	28DH50	Power Tool	2.3	Y
			Citric Acid	1.8	9
One Component Inorganic Zinc	Devoe	306	Power Tool	5.6	Note 1 9 Yr
			Citric Acid	4.6	10
One Component Inorganic Zinc	Mobil	13G10	Power Tool	2.2	Note 1
			Citric Acid	1.6	Note 2
Modified Inorganic Zinc	Porter	352	Power Tool	3.0	Note 1 9 Yr
			Citric Acid	2.5	10
One Component Epoxy Zinc Rich	Napko	1355	Power Tool	5.6	9
			Citric Acid	4.5	9
Polyamide Epoxy	Carboline	193HB	Power Tool	5.6	Note 1 9 Yr
			Citric Acid	4.3	Note 1 9 Yr
Polyamide Epoxy	Devoe	208	Power Tool	2.4	Failed 30 Mo
			Citric Acid	2.0	Failed 30 Mo
Polyamide Epoxy	Napko	5616	Power Tool	2.4	Note 1 9 Yr
			Citric Acid	7.0	Note 1 9 Yr
Alkyd	Imperial	62	Power Tool	4.7	8
			Citric Acid	3.4	
One Component Epoxy	INT	NEA200	Power Tool	3.4	1:
			Citric Acid	3.3	Y
Ketamine Epoxy	INT'	TTA424	Power Tool	5.9	Note 3
			Citric Acid	5.8	8

Note 1: Failed in Repair Area
Note 2: Failed in Top Half of Panel, Repair Area Rust Grade 10
Note 3: Failed in Weld Area

2.5 Inorganic Zinc Primers Applied Over Four Types of Abrasives

To investigate the possible impact of abrasive selection on paint performance, a limited test program was initiated to test the performance of inorganic zinc primers applied over four different abrasives. Four alkyl inorganic zinc primers were applied to two sets of panels prepared using a coal slag, a mineral sand, a silica sand, and GL-40 steel grit abrasives. Film thicknesses within a supplier set were controlled by applying the materials to all four panels simultaneously. Film thicknesses between supplier sets ranged from 2.2 to 5.3 roils. All panels were then exposed on an exterior test rack. After 60 days, one set was removed and placed in a salt fog cabinet for 6000 hours. The salt fog test was performed in accordance with ASTM B117. After 6000 hours, all panels had a rust grade of 10. Table VII contains the ten year test fence exposure results. In two cases the rust grades were all 10 showing no difference between abrasive blast media tested. In two other cases, the GL40 steel grit blasted panels had the best performance (Rust Grade 10) with mineral sand and silica sand alternating by one rust grade. No firm conclusions could be drawn at ten years and 6000 hours of salt fog to demonstrate superiority or unsuitability of the abrasives tested.

TABLE VII

INORGANIC ZINC PRIMERS APPLIED OVER STEEL PANELS ABRASIVE BLASTED WITH FOUR DIFFERENT TYPES OF ABRASIVE BLAST MEDIA

SUPPLIER	PRODUCT NO.	RUST GRADES BY ABRASIVE TYPE(DFT)* GL40	MINERAL SAND	SILICA SAND	COAL SLAG
Carboline	Carbo Zinc 11	10(4.7)	10(5.3)	10(4.5)	10(5.3)
Devoe	304	10(4.8)	10(4.6)	10(4.4)	10(4.4)
International	2410/2411	9(2.5)	8(2.2)	8(2.3)	-
Mobi1	13F12	10(2.6)	9(2.9)	10(2.3)	-

* DFT= Dry Film Thickness

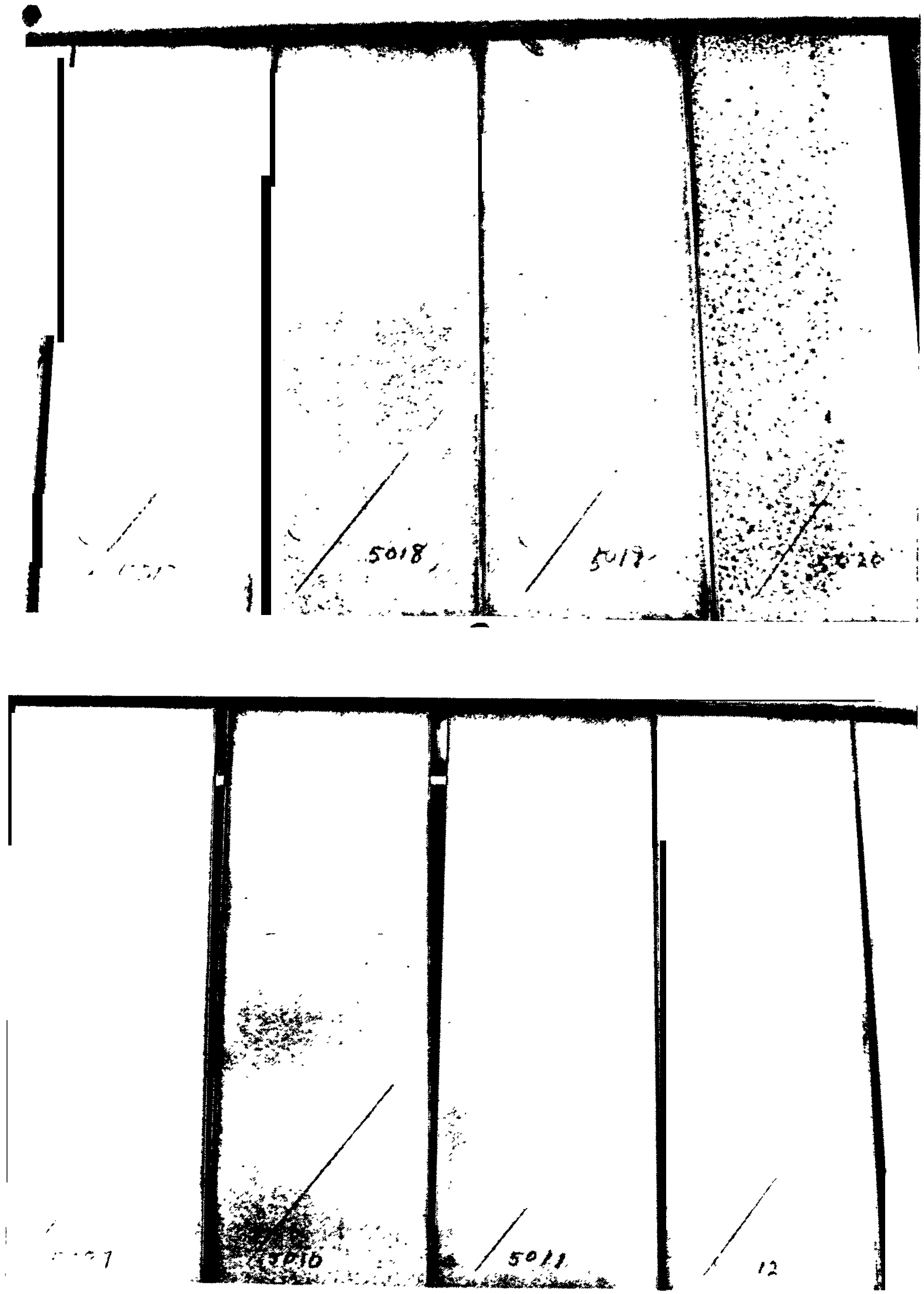

FIGURE 2.9: INORGANIC PRIMERS OVER VARIOUS ABRASIVES

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